28 AUG 1935
BOSCOMBE DOWN, WILTS.
M.O. 331i

120

COPY FOR OFFICIAL USE

AIR MINISTRY

METEOROLOGICAL OFFICE

PROFESSIONAL NOTES NO. 69

(Prof. Notes)

(*Ninth Number of Volume V*)

THE FREQUENCY OF DAYS WITH SPECIFIED DURATION OF SUNSHINE

By E. G. BILHAM, B.Sc., D.I.C.
and
LILIAN F. LEWIS, B.Sc.

Published by the Authority of the Meteorological Committee
Crown Copyright Reserved

LONDON
PRINTED AND PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE
To be purchased directly from H.M. STATIONERY OFFICE at the following addresses:
Adastral House, Kingsway, London, W.C.2; 120 George Street, Edinburgh 2;
York Street, Manchester 1; 1 St. Andrew's Crescent, Cardiff;
80 Chichester Street, Belfast;
or through any Bookseller

1935

Price 3*d*. Net

40-57-69

THE FREQUENCY OF DAYS WITH SPECIFIED DURATION OF SUNSHINE

By E. G. BILHAM, B.Sc., D.I.C. and LILIAN F. LEWIS, B.Sc.

Monthly frequency tables of daily duration of sunshine within specified limits for a selection of stations have been given in the Monthly Supplement to the *Daily Weather Report* since 1917 and similar data have been given in the Annual Summary of the *Monthly Weather Report* (Table VI) since 1913. The number of stations for which data are printed in the Annual Summary, Table VI, is 20 and of the stations in this table for 1932, 14 had appeared since 1913. For these stations 20 year averages could therefore be computed. Four more stations had appeared for 12 years. It was thus possible to compute averages for 18 stations based on at least 12 years of observation. The positions of the 18 stations are indicated by dots, numbered to correspond with the entries in Table I, in Figs. 1a and 1b

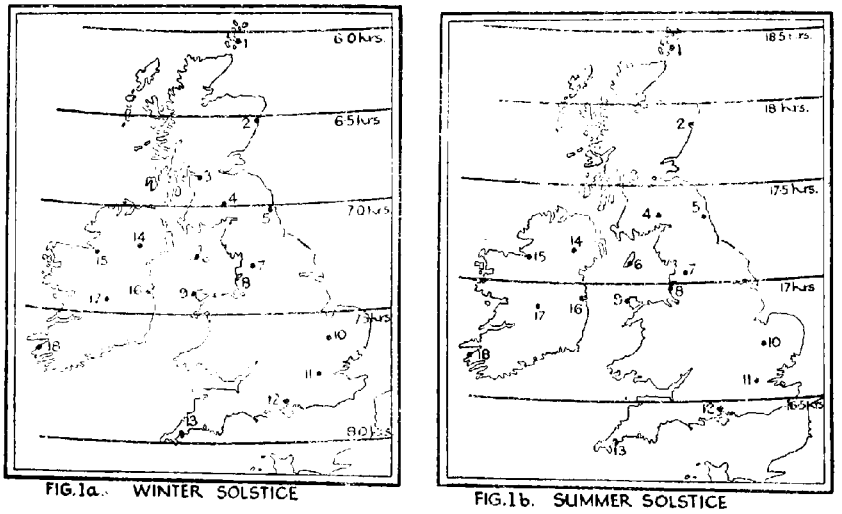

FIG. 1a. WINTER SOLSTICE

FIG. 1b. SUMMER SOLSTICE

FIG. 1.—POSITIONS OF STATIONS AND NUMBERS OF HOURS OF DAYLIGHT AT THE SOLSTICES.

upon which are drawn lines indicating the maximum possible duration of sunshine at the Solstices. These times refer to the interval between the ascending and descending transits of the centre of the sun across the horizon, allowance being made for atmospheric refraction.

The averages obtained show the mean monthly and annual frequencies (both actual frequencies and percentages) of days having the following duration of sunshine.

(*a*) No sunshine
(*b*) 0·1 hr. to 3·0 hr.
(*c*) 3·1 hr. to 6·0 hr.
(*d*) 6·1 hr. to 9·0 hr.
(*e*) More than 9 hours.

The results are included in Table II of a new publication entitled " Averages of Bright Sunshine for the British Isles " (M.O.377). Table I of this paper presents the data in the form of " running percentages ". The four columns for each month give the percentage frequencies of days with no sunshine, more than 3 hours, more than 6 hours, and more than 9 hours. The percentage frequency of days with sunshine duration equal to 0·1 hr. or more can be found by subtracting the frequency of days with no sunshine from 100. We thus have four points from which to construct a curve showing the percentage frequency of days with sunshine duration exceeding a given value S hours at a given station in a given month. A fifth point is furnished by the consideration that sunshine is not normally registered by a Campbell-Stokes recorder when the sun is less than 3° above the horizon. The percentage frequency of days with duration exceeding the calculated duration of " recordable " sunshine defined in this way may therefore be taken to be zero.

The 12 monthly curves for Kew Observatory are shown in Fig. 2 and Fig. 3. From such curves it is possible by interpolation to obtain the approximate value of the percentage frequency of days having more than any specified duration of sunshine within the recordable limits. Sets of curves based on the four points given by the tabulations were drawn for the following selected stations :—

Aberdeen Observatory,
Eskdalemuir Observatory,
Cambridge (Botanic Gardens),
Kew Observatory,
Falmouth Observatory,
Valentia Observatory.

From the curves, the percentage frequency of days with sunshine exceeding half the astronomically possible duration was read off in each month. The values are given to the nearest whole number in Table II.

The data in Table I and Table II for the six selected stations are shown in Figs. 4 to 9, in the form of curves which represent the variation throughout the year of the percentage frequency of days with—

(A) No sunshine,
(B) More than 3 hours of sunshine,
(C) More than 6 hours of sunshine,
(D) More than 9 hours of sunshine,
(E) More than half the possible duration of sunshine.

The days included in category (E) are of special interest because they are selected with reference to a criterion which eliminates variation due to latitude and solar declination. If we consider a particular month (other than an equinoctial month) we have to remember when looking at Table I that the average interval between sunrise and

TABLE I.—PERCENTAGE FREQUENCY OF DAYS WITH SUNSHINE 6 HOURS, (D) MORE

No. of Station	Name of Station	January				February				March				April				May				June			
		No sunshine	>3 hours	>6 hours	>9 hours	No sunshine	>3 hours	>6 hours	>9 hours	No sunshine	>3 hours	>6 hours	>9 hours	No sunshine	>3 hours	>6 hours	>9 hours	No sunshine	>3 hours	>6 hours	>9 hours	No sunshine	>3 hours	>6 hours	>9 hours
1	Deerness 1913–32	47	10	0	—	35	26	6	0	23	38	17	2	11	59	35	15	11	60	40	20	13	58	42	25
2	Aberdeen 1913–32	40	22	2	—	31	32	12	0	19	46	24	5	12	62	35	14	11	65	43	21	7	68	47	29
3	Renfrew 1921–32	51	14	1	—	39	22	6	0	21	43	19	3	12	56	36	16	11	65	40	19	10	65	47	26
4	Eskdalemuir 1913–32	51	14	3	—	38	26	10	0	22	44	23	6	13	58	33	13	12	60	39	20	8	65	45	28
5	Cockle Park 1913–32	43	25	4	—	35	32	11	0	21	48	25	7	16	59	38	17	11	65	45	24	7	72	50	28
6	Douglas 1913–32	42	26	6	—	32	34	15	1	18	57	33	9	10	65	49	29	10	69	50	34	8	74	55	38
7	Stonyhurst 1913–32	49	14	1	—	37	28	7	0	21	45	22	4	10	58	35	15	9	63	42	26	5	67	47	30
8	Southport 1921–32	44	21	3	—	32	32	12	0	17	56	29	7	9	66	44	23	5	70	51	31	5	74	56	39
9	Holyhead 1921–32	39	25	6	—	27	42	19	2	14	58	32	11	9	71	50	26	7	73	56	36	6	73	57	42
10	Cambridge 1913–32	43	24	3	—	34	33	13	0	21	51	28	7	13	57	34	16	9	69	53	34	5	73	53	35
11	Kew Observatory 1913–32	46	21	3	—	31	29	9	0	20	47	23	4	11	58	35	14	7	71	52	32	5	75	55	33
12	Southampton 1913–32	40	24	5	—	28	36	18	1	15	55	31	8	10	64	42	19	6	73	55	37	5	78	61	43
13	Falmouth 1913–32	35	28	7	0	25	39	17	1	14	58	35	11	9	70	51	31	10	71	52	34	6	77	64	45
14	Armagh 1913–32	41	21	3	—	28	33	11	1	19	50	24	7	10	62	41	19	10	64	42	21	9	63	43	27
15	Markree Castle 1913–32	42	17	2	—	33	31	9	0	19	48	22	5	10	62	42	16	10	66	42	23	10	59	39	23
16	Dublin (Phœnix Park) 1913–32	36	25	5	—	29	36	15	1	18	52	26	7	9	64	43	21	9	66	45	25	6	69	50	31
17	Birr Castle 1921–32	39	24	3	—	33	35	9	0	16	53	27	6	11	67	44	17	10	67	43	22	10	64	43	23
18	Valentia Observatory 1913–32	38	19	3	—	29	32	12	1	17	53	28	10	10	66	44	22	11	66	48	28	11	60	45	29

NOTE.—An entry "—" means that an observation of

Duration (A) Nil, (B) More than 3 Hours, (C) More than than 9 Hours.

July				August				September				October				November				December				Year				No. of Station
No sunshine	>3 hours	>6 hours	>9 hours	No sunshine	>3 hours	>6 hours	>9 hours	No sunshine	>3 hours	>6 hours	>9 hours	No sunshine	>3 hours	>6 hours	>9 hours	No sunshine	>3 hours	>6 hours	>9 hours	No sunshine	>3 hours	>6 hours	>9 hours	No sunshine	>3 hours	>6 hours	>9 hours	
15	52	29	15	13	51	26	11	16	42	21	6	21	36	10	1	37	16	2	—	57	5	0	—	25	38	19	8	1
9	59	34	16	11	56	32	12	13	55	31	10	19	47	20	2	31	33	5	—	39	17	0	—	20	47	24	9	2
12	57	34	12	9	53	30	10	17	55	31	6	22	39	16	1	43	22	5	0	54	12	1	—	25	42	22	7	3
9	54	32	14	11	51	27	9	18	49	24	8	28	38	20	3	38	28	9	0	54	16	2	—	25	42	22	9	4
11	63	37	18	9	62	35	16	13	59	36	10	21	45	23	3	31	34	11	0	40	21	1	—	21	49	27	10	5
9	65	48	29	8	63	43	23	13	59	40	17	21	45	23	4	31	32	10	0	45	22	2	—	21	51	31	15	6
9	59	36	18	11	59	33	15	15	54	31	10	21	40	18	1	36	24	5	0	50	14	1	—	23	44	23	10	7
6	67	45	26	7	65	41	24	13	60	36	13	16	49	25	3	33	26	8	0	44	18	1	—	19	50	29	14	8
9	67	47	28	8	61	40	24	13	59	37	14	19	48	25	5	31	31	11	0	42	16	1	—	19	52	32	16	9
8	68	45	25	5	71	47	25	12	63	41	14	17	52	26	2	35	33	9	0	49	21	1	—	21	51	29	13	10
5	66	46	25	4	70	45	22	10	62	39	15	16	47	18	1	37	27	7	0	47	19	1	—	20	49	28	12	11
6	70	53	32	5	71	52	27	9	65	45	21	15	53	28	3	29	36	13	0	40	25	3	—	17	54	34	16	12
7	72	56	35	6	70	52	29	12	63	43	21	15	52	28	5	25	37	13	0	30	27	5	—	10	55	35	17	13
11	53	29	13	13	57	32	11	15	51	30	10	23	41	19	2	33	30	9	0	45	18	1	—	21	45	24	9	14
13	51	29	15	13	52	28	10	17	50	25	5	23	39	15	1	35	27	5	0	43	14	0	—	22	43	22	8	15
7	63	40	19	9	64	39	17	14	57	34	13	20	47	21	2	29	36	11	0	37	23	2	—	19	50	27	11	16
11	54	29	13	11	56	32	13	15	51	33	9	20	42	18	2	35	32	7	0	41	20	1	—	21	47	24	9	17
12	53	36	20	13	57	37	19	17	51	31	12	23	42	19	3	31	28	10	0	38	15	2	—	21	45	26	12	18

more than 9 hours' duration is impossible.

sunset decreases from north to south in the summer half year and increases from north to south in the winter half-year. Similarly, in considering the results for a single station, the seasonal variation in the duration of daylight has to be borne in mind. These consider-

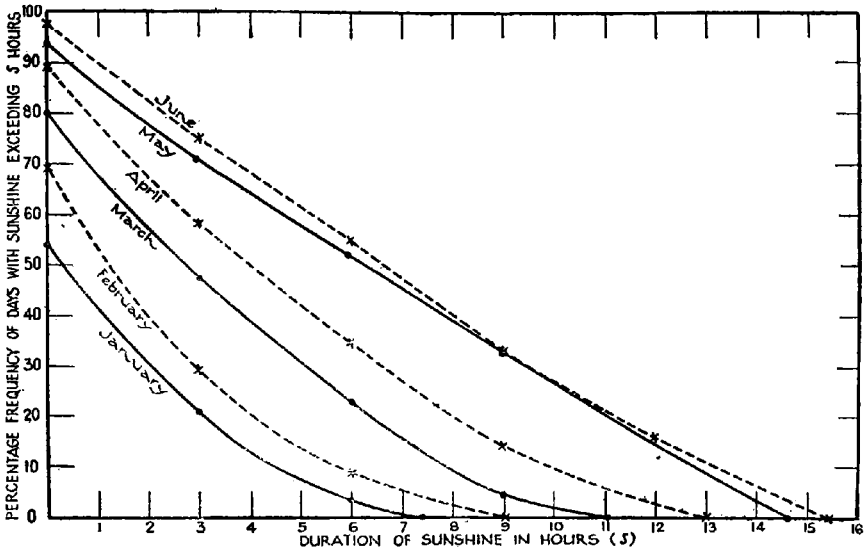

FIG.2. KEW OBSERVATORY

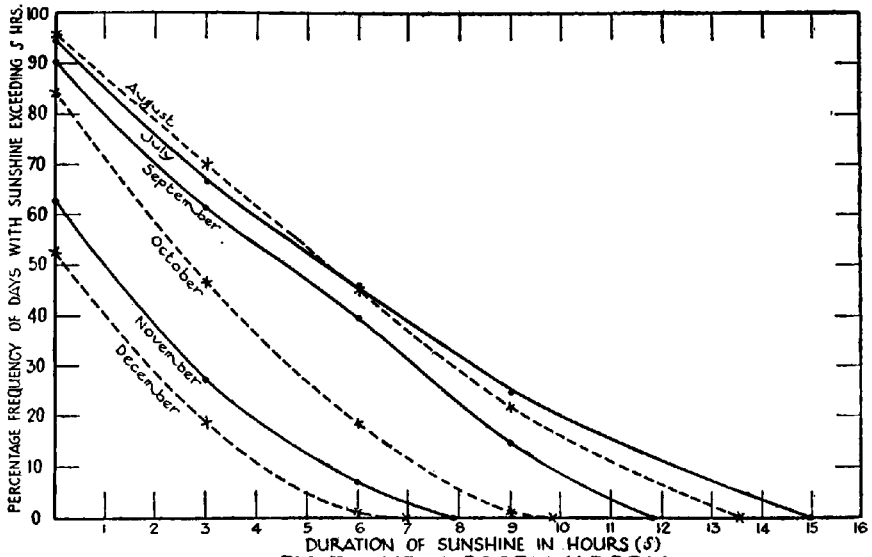

FIG.3. KEW OBSERVATORY.

ations make it difficult to draw conclusions with regard to the relative " sunniness " of different places and seasons from data such as those of Table I. The criterion adopted for category (E) varies with the place and the time of year in such a manner as to eliminate these

To face p. 6

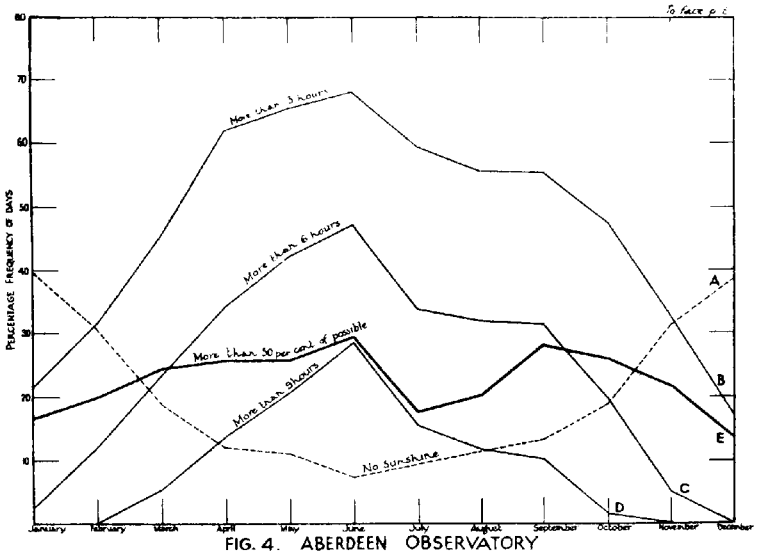

FIG. 4. ABERDEEN OBSERVATORY

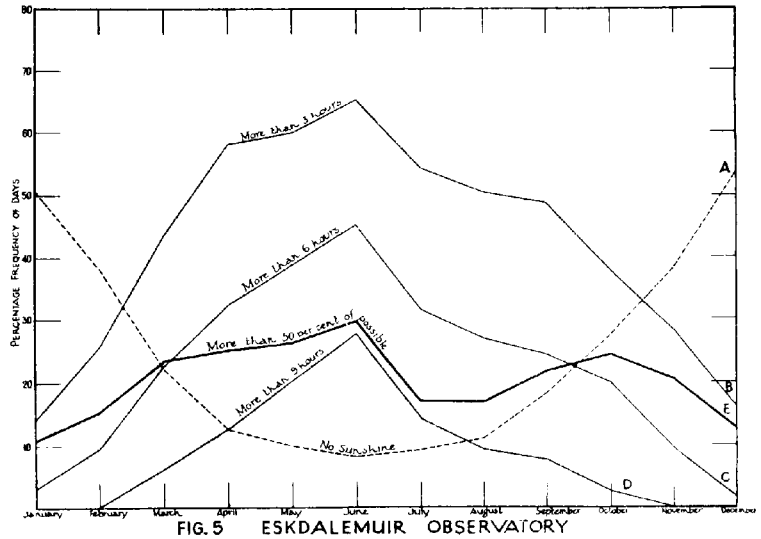

FIG. 5 ESKDALEMUIR OBSERVATORY

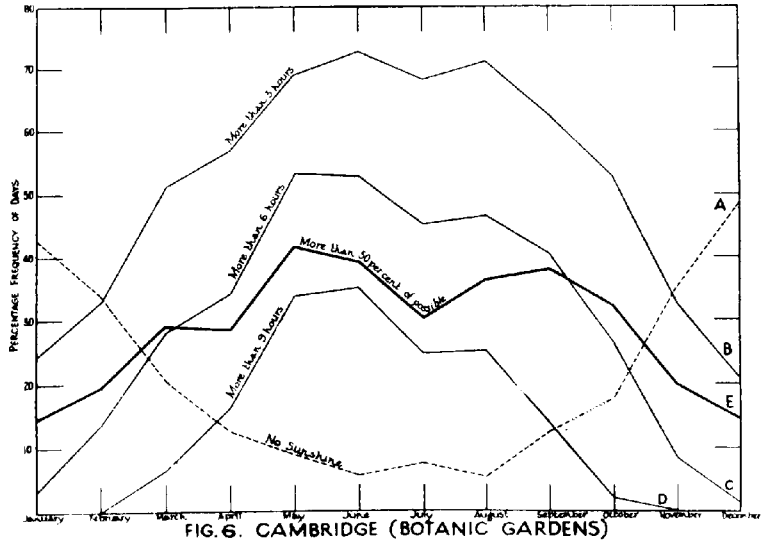

FIG. 6. CAMBRIDGE (BOTANIC GARDENS)

To face p 7

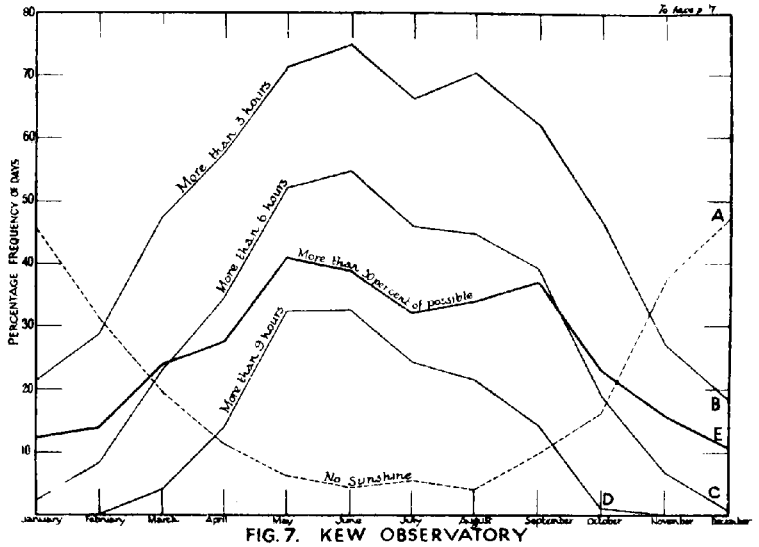

FIG. 7. KEW OBSERVATORY

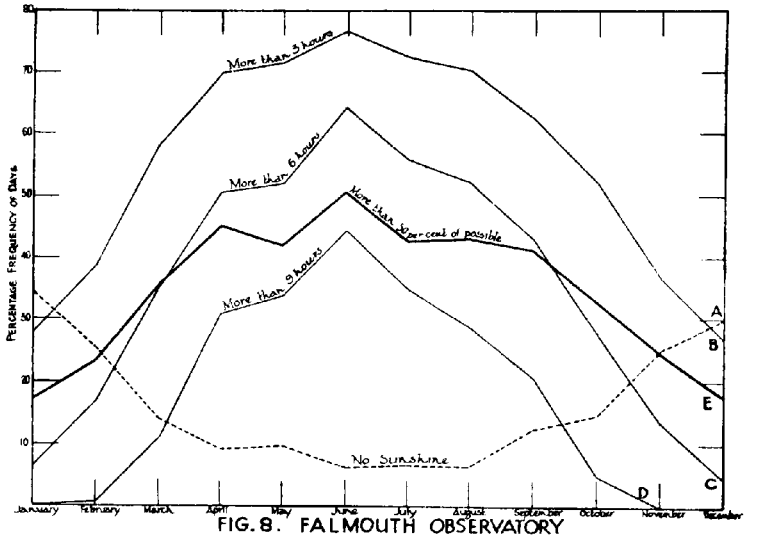

FIG. 8. FALMOUTH OBSERVATORY

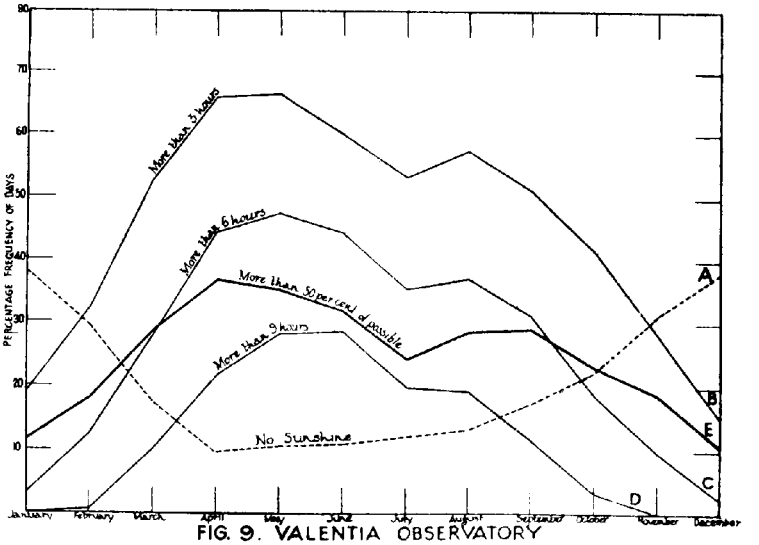

FIG. 9. VALENTIA OBSERVATORY

TABLE II.—PERCENTAGE FREQUENCY OF DAYS WITH SUNSHINE DURATION MORE THAN HALF THE POSSIBLE

	Aberdeen		Eskdale-muir		Cam-bridge		Kew Obser-vatory		Falmouth		Valentia Obser-vatory	
	Half possible sunshine	Number of days	Half possible sunshine	Number of days	Half possible sunshine	Number of days	Half possible sunshine	Number of days	Half possible sunshine	Number of days	Half possible sunshine	Number of days
	hrs.	%	hrs.	%	hrs.	%	hrs.	%	hrs.	%	hrs.	%
January ..	3·69	17	3·86	11	4·11	14	4·17	12	4·27	17	4·13	12
February ..	4·68	20	4·77	15	4·91	20	4·94	14	4·99	23	4·93	18
March ..	5·87	25	5·88	23	5·89	29	5·90	24	5·91	36	5·89	29
April	7·10	26	7·03	25	6·91	29	6·89	28	6·85	45	6·91	37
May	8·21	26	8·05	26	7·81	41	7·77	41	7·67	42	7·80	35
June	8·85	30	8·63	30	8·30	39	8·24	39	8·12	50	8·29	32
July	8·57	18	8·37	17	8·08	30	8·03	32	7·92	43	8·07	24
August ..	7·57	20	7·47	17	7·31	36	7·27	34	7·21	43	7·29	29
September ..	6·39	28	6·36	22	6·33	38	6·31	37	6·30	41	6·32	29
October ..	5·17	26	5·22	24	5·31	32	5·33	24	5·36	33	5·31	23
November ..	4·03	22	4·17	21	4·39	20	4·43	16	4·51	24	4·40	19
December ..	3·35	14	3·57	13	3·87	14	3·93	11	4·03	17	3·89	11

astronomical factors and the resulting data may be regarded as representing the average frequency with which a certain state of the sky occurs during the period of daylight at the six selected stations. For the purpose of ready comparison the six curves marked E in Figs. 4 to 9 are assembled together in Fig. 10. Days with more than half the possible duration of sunshine, category (E), are referred to below as " sunny days ".

Discussion of Results.—I.—Consider first the results for the whole year in Table I. The following points emerge :—

(1) Sunless days occur on about 1 day in 6 at Falmouth and Southampton as compared with 1 day in 4 at Deerness, Renfrew and Eskdalemuir.

(2) Days with more than 9 hours are twice as frequent on the south coast of England as in the Orkney Islands in spite of the considerably greater length of the summer day in the higher latitude.

(3) At the majority of stations about half the days have more than 3 hours' sunshine.

Passing on to the months we see that—

(4) It is only in December and January that the frequency of sunless days equals or exceeds 50 per cent. at any station.

(5) Sunless days are much less frequent on the south-west coast of England during the winter months, November to February, than in other districts. For instance, the percentage frequency of sunless days in the 4 months at Falmouth is 29, compared with 33 at Dublin, 34 at Southampton and Valentia, 40 at Kew Observatory and 47 at Renfrew.

(6) The frequency of sunless days in August is very low at Kew Observatory : it amounts to only 4 per cent. and is the lowest figure in the whole table.

(7) In the spring months, March and April, the frequency of days with more than 9 hours is greater in the western coastal districts of England and in south-west Ireland than elsewhere.

II.—The curves (drawn for each month at six selected stations from the data in Table I) showing the percentage frequency of occurrence of days with more than a given duration of sunshine, are slightly concave upwards, indicating that the frequency of days with duration between limits such as $S - \frac{1}{2}$ hr. and $S + \frac{1}{2}$ hr. tends to decrease as S increases. For the summer months, however, the curvature becomes less pronounced and, at some stations, the curves approximate very closely to straight lines as is clearly shown in the graphs for Kew Observatory reproduced in Figs. 2 and 3. This means that the frequency of days with duration S hours is practically independent of the value of S or, in other words, there is no particular duration of sunshine within the limits 0·1 hours and 9 hours that is markedly more probable than any other in one of the summer months. For Kew Observatory a special evaluation was made of the frequency of days in June with duration exceeding 12 hours. The point so obtained is marked on the curve, and is seen to lie very nearly on the straight line passing through the other points. The conclusion just enunciated applies therefore for values of S up to 12 hours in that month. This form of frequency distribution is unusual in meteorology. In the case of rainfall, the percentage frequency of days with small falls is greatly in excess of the percentage frequency of days with larger falls and the running percentage curve is of logarithmic form.*

III.—Figs. 4 to 9 do not call for special comment but many interesting points arise out of Fig. 10 in which curves showing monthly percentage frequencies of days with duration more than 50 per cent. of the possible ("sunny days") are drawn for the six selected stations. The highest percentage of sunny days occurs in late spring or early summer : in April at Valentia, May at Cambridge and Kew Observatory and June at Falmouth, Aberdeen and Eskdalemuir. The following further points may be stressed :—

(1) The large number of sunny days experienced throughout the year on the south coast of England (represented by Falmouth) compared with other districts, particularly in comparison with Scottish stations.

(2) The sudden decrease in the number of sunny days, which occurs at all stations in July.

(3) The second maximum which occurs in early autumn, generally in September, though it is delayed until October at Eskdalemuir and is almost absent at Falmouth.

* *See* The frequency distribution of daily rainfall, by E. G. Bilham and A. C. Lloyd. *London, Brit. Rainf. 1932*, pp. 268–77.

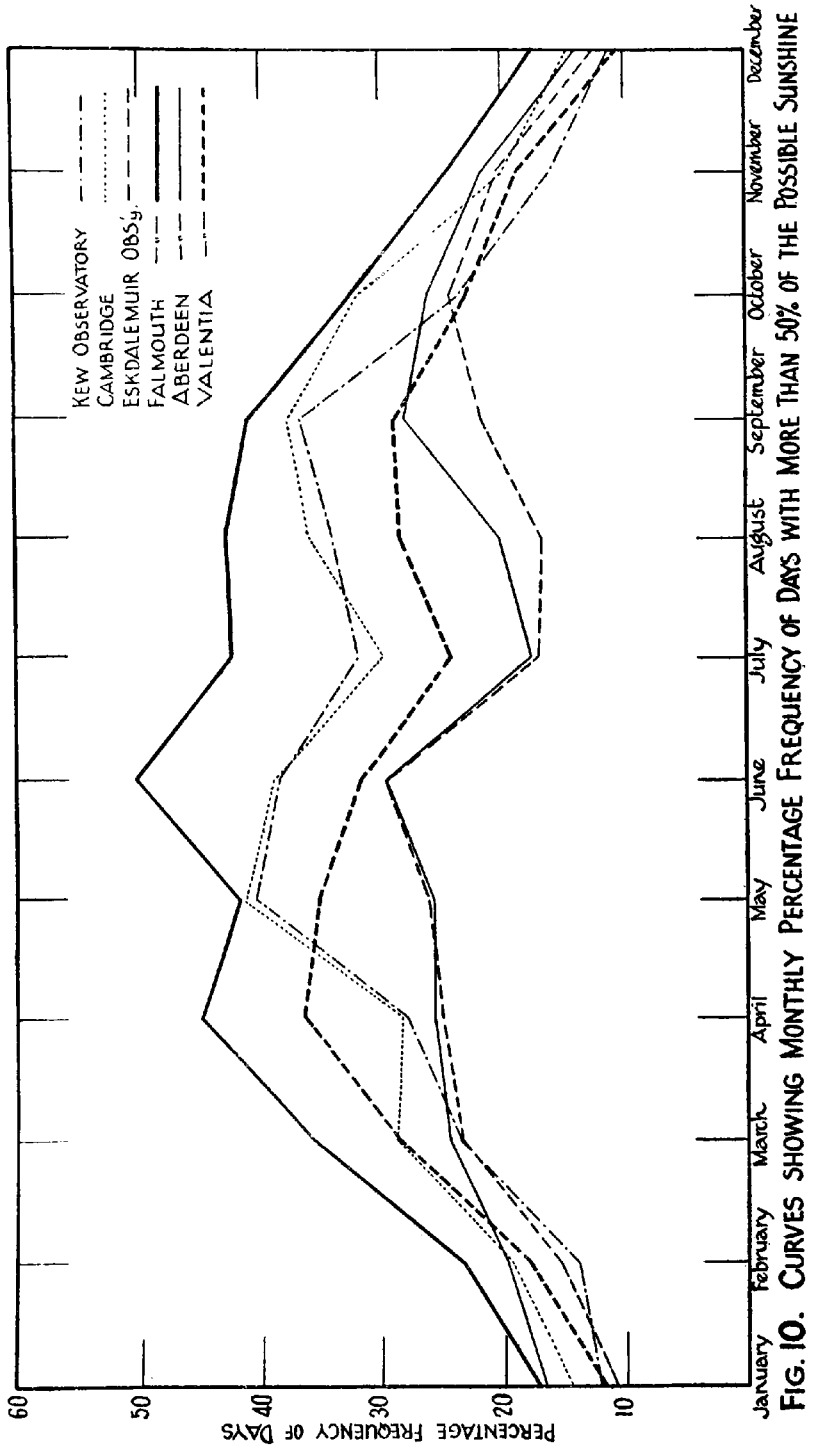

FIG. 10. CURVES SHOWING MONTHLY PERCENTAGE FREQUENCY OF DAYS WITH MORE THAN 50% OF THE POSSIBLE SUNSHINE

(4) The almost equally high percentages of sunny days at Kew and Cambridge during the 6 months, April to September, and the decided deficiency of sunny days at Kew during the winter 6 months, almost certainly due to the pollution of the air over London.

(5) The similarity of the curves for Eskdalemuir and Aberdeen during the months March to July and the higher frequency of sunny days at Aberdeen in the remaining months. [From considerations of heights and geographical position in relation to the prevailing rain-bearing winds, one would expect Aberdeen to enjoy an advantage over Eskdalemuir in respect to sunshine at all seasons. In late spring and early summer, however, north-easterly winds are more frequent than at other seasons and, under these conditions, low cloud and drizzle prevail at Aberdeen and its sunshine records are thus brought into approximate equality with those of Eskdalemuir.]

(25449) Wt. 3738/1595 625 7/35 Hw. G.371